

PILOT UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR (UA2) TEST

UA2 Test Unit

The pilot UASBR or UA2 complimented the operation of the main UASBR. The primary objective of the UA2 was to develop operation parameters for the main UASBR. The UA2, a transparent column, visually represented the main UASBR where sludge could be monitored for color and size and where the effects of a change in operational parameter such as upflow velocity could be observed prior to making operational changes to the main unit. Also, at the end of the testing period, the UA2 was used to treat low selenium drainage water from Firebaugh Canal Water District.

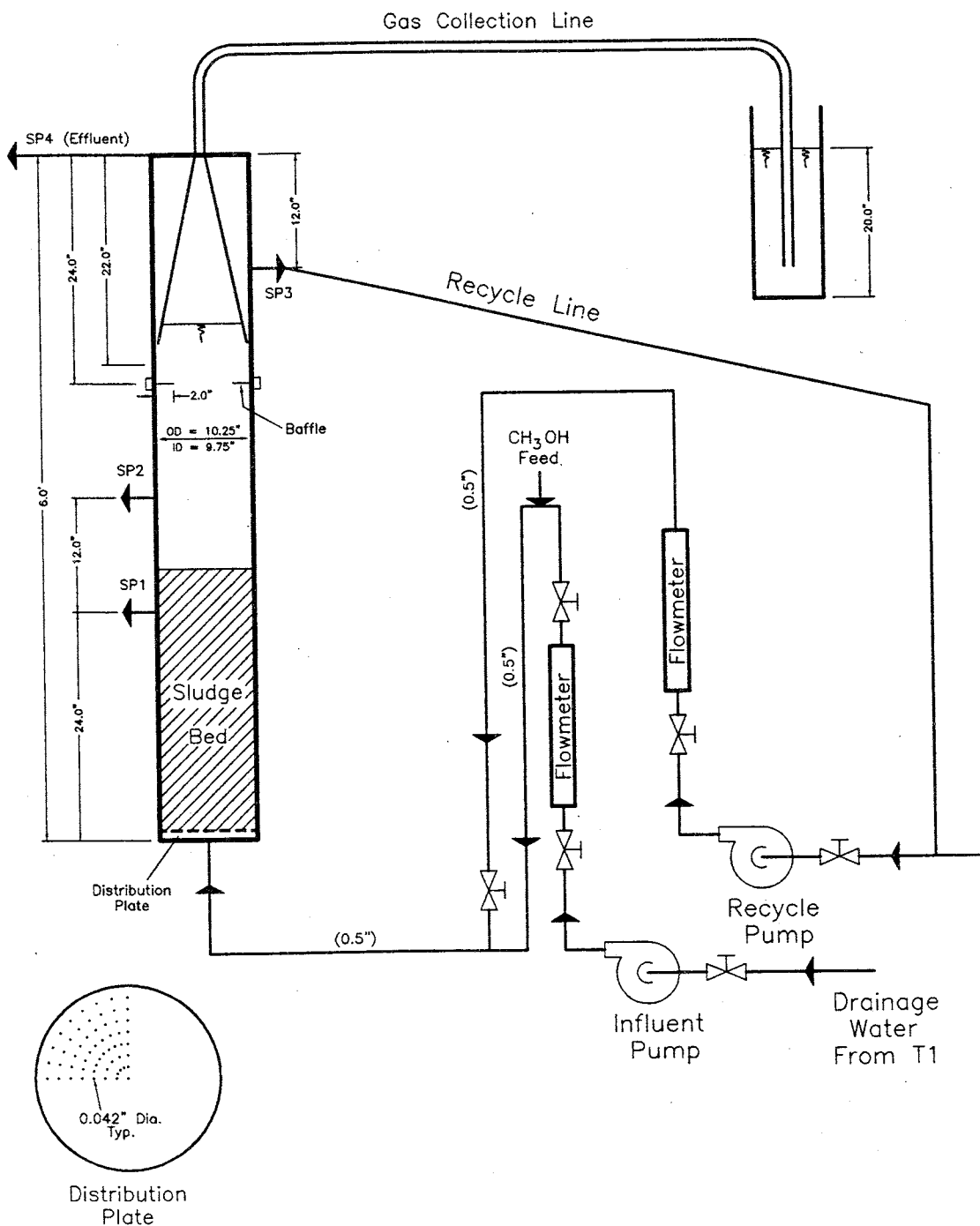
The UA2 consisted of a 10-inch diameter Plexiglas column, 6 feet high and fitted with a gas/solids separator cone, baffle and a recycle line. The UA2 system was fitted with influent and recycle pumps, influent and recycle flow meters, and a methanol injection system. The schematic for the UA2 system is shown in Figure 76.

UA2 Operations - March 16, 1994 through November 16, 1995

Maintaining the integrity of the sludge and sludge bed throughout the entire program testing of the UASBR process was a continual problem. Gas is generated in the sludge bed as a result of the process. The gas posed two basic problems. Gas bubbles would be entrapped in the sludge bed, forming pockets that in turn caused short circuiting through the unit. The second problem occurred as gas bubbles floated up through the unit. The bubbles attracted sludge granules, sludge fines, and other bubbles and formed a mass or "clumps" as the bubbles passed up through the sludge bed and floated to the surface. These clumps contained organisms that are vital in the treatment process. For the process to be effective, these organisms must remain in the sludge bed and be available to treat the incoming water. The primary concerns of operations were to ensure an even distribution of flow through the sludge bed; to prevent degradation of the sludge granules; to release gas from the sludge bed; to prevent agglomeration of the gas and sludge that would form into clumps; and to break up the agglomeration once it occurred. Almost all operational decisions were based on these concerns. As a standard daily maintenance practice, operation personnel tapped the outside of the reactor at the sludge bed level with a rubber mallet to relieve gas that had accumulated.

Operation of the UA2 commenced on March 16, 1994 (Day 548), and ceased on November 16, 1995 (Day 1158). The first seven weeks of operation involved shake-down of the pilot system and testing the stability of sludge. Recording of operational data started on May 10, 1994 (Day 603) while laboratory analyses commenced on June 1, 1994 (Day 625).

From March 16 (Day 548) through April 27 (Day 590), the UA2 was operated to test the stability of the granular bakery sludge. It was loaded with 8 gallons of the black bakery sludge and started at a feed flow rate of 0.12 gpm (upflow velocity of 0.231 gpm/ft^2) with a methanol dose of 275 mg/L. On March 23 (Day 556), the black granules had turned brown and white, likely because of the oxygen content of the influent drainage water. The unit was turned off for 24 hours then restarted with influent limited to 0.1 gpm for 30 minutes a day with a pure methanol



**Figure 76. Pilot - Scale Upflow Anaerobic
Sludge Blanket Reactor Schematic
(UA2)**

dosage of 25 mL per day and a recycle flow of 0.1 gpm. The recycle flow was turned off on April 17 while the influent rate and pure methanol dosage remained unchanged. When this test was complete, on April 27, the sludge granules gradually had turned gray and black and exhibited decent settling characteristics. Fines were present in the water above the sludge bed for the entire period.

On April 27, 1994, the UA2 was shut down to replace the bakery sludge with a composite sludge taken from three locations of the main UASBR: port 2, port 3 and surface scum of the UASBR. The sludge volume placed into the UA2 was 7.4 gallons (28 liters) with a settled sludge depth of 17 inches. The UASBR sludge was a mixture of anaerobic digester sludge from the Fresno Wastewater Treatment Plant and activated sludge from the Selma-Kingsburg-Fowler Treatment Plant. From April 27 to May 9, 1994, the UA2 was operated with only a recycle flow of 0.12 gpm (upflow velocity of 0.231 gpm/ft²). It was observed that gas bubbles generated in the sludge bed attracted sludge fines and particles as the bubbles rose to the surface. A portion of the sludge particles would then fall back on top of the sludge bed as the bubbles dispersed at the surface. On May 9, 1994 (Day 602), testing with drainage water commenced, during which influent flow was added at 0.05 gpm and the recycle flow rate was doubled to 0.2 gpm (upflow velocity of 0.483 gpm/ft²). In this mode, nitrate and dissolved oxygen concentrations both decreased. The recycle flow rate had to be adjusted daily because sludge fines and gas accumulated in the recycle line and restricted the recycle flow. The recycle flow rate often dropped to zero overnight. Sludge fines and granules would agglomerate and form into clumps in the reactor during normal operations. To agitate the sludge bed and break down these clumps of sludge and gas, the recycle rate was increased to 1.0 gpm for five minutes. At the end of this test period, the sludge bed was about 21 inches deep and consisted of brown granules at the bottom of the bed with black fine on top of the granule layer.

From May 24 (Day 617) through September 14, 1994 (Day 730), the UA2 was operated to mimic operation of the main UASBR. The feed flow rate ranged between 0.1 and 0.12 gpm (upflow velocity of between 0.193 and 0.231 gpm/ft²), the recycle was off, and the methanol dosage was targeted at 300 mg/L. The sludge bed was agitated daily to release gas generated during operations.

During the first month of this test period, the sludge bed's depth decreased 3 inches but an increase in the depth of the brown granules was observed. The granules at the bottom of the bed had a reddish tint. Fines were noticed to be moving throughout the reactor and accumulating on the outside of the cone (gas/solids separator) and along the reactor wall by the bottom of the cone. The wall of the reactor above the sludge bed was a red and orange color. The sludge bed had increased from 15 inches to 21 inches during the last month of this period. The top 2 to 3 inches of the sludge bed contained fines that were black and dark brown, and the remainder of the bed consisted of granules that were brown.

The next test period was from September 15, 1994 (Day 731) through November 2, 1995 (Day 1144), during which the primary goals were to evaluate the treatment efficiency of the process at a higher flow rate and observe the stability of the sludge under the new parameters. Initially, the UA2 was operated at an influent flow rate of 0.2 gpm (upflow velocity of 0.386 gpm/ft²), without a recycle flow. The sludge bed was mixed daily for about 2 minutes using the recycle system. Actual methanol dosage rates ranged between 182 mg/L and 485 mg/L.

Problems were encountered maintaining a uniform flow through the sludge bed. One means to accomplish this was to agitate and mix the sludge bed on a daily basis by pulsing additional flow through the reactor using the recycle system. Pulse duration was changed twice during this period from the initial daily duration of 2 minutes. On March 3, 1995 (Day 900), the duration was increased to 5 hours per day, but on April 14 (Day 942) it was decreased to 20 minutes per day because of sludge granule disintegration at the longer duration.

A recycle flow was added to the operation parameters on two occasions during this test period. The primary purposes of the recycle flow were to prevent sludge granules, sludge fines, and gas from agglomerating into clumps and to help break up the clumps once they were formed. The first occasion was for eight days, starting January 7, 1995 (Day 845). The second occasion was for one week, starting February 23, 1995 (Day 892). On both occasions, the recycle flow was terminated because the sludge granules decreased in size as result of the recycle flow. Problems were also encountered in maintaining a constant recycle flow rate because sludge fines and gas restricted flow at various locations in the recycle system.

The sludge bed expanded about 8 inches during the first month of the test. On October 20, 1994 (Day 766), 3 gallons of brown granules were removed from the middle of the sludge bed to improve mixing of the bed and distribution of flow through the bed. The remaining sludge bed depth measured 17 inches settled and expanded 6 inches when operations resumed.

Sludge was removed from the reactor on three other occasions to improve the mixing of the bed. Four gallons were removed on January 30, 1995, (Day 868); 2 gallons were removed on June 15, 1995 (Day 1004); and another 2 gallons were removed on October 5, 1995 (Day 1116). On June 29, 1995 (Day 1018), the entire bed was replaced with sludge obtained from the main UASBR to compare treatment efficiency of the UA2 with that of the main UASBR.

Testing with the UA2 was temporarily stopped for three weeks, starting March 10, 1995 (Day 907), and due to flooding of the Adams Avenue site. On another note, the UA2 was taken apart and cleaned on three occasions in 1995: January 30, May 2, and October 5. Also the phosphate feed dosage into the raw drainage water was increased from 0.25 mg/L to 1.3 mg/L on September 29, 1995 (Day 1079).

Testing using low-selenium drainage water was performed from November 2 (Day 1144) through the end of testing operations on November 16, 1995. Drainage water with selenium concentrations averaging 35 ug/L was trucked from Firebaugh Canal Water District. The feed flow rate into the unit was 0.2 gpm (upflow velocity of 0.386 gpm/ft²) until November 11, when it was decreased to 0.1 gpm (upflow velocity of 0.193 gpm/ft²). Methanol dosage ranged between 370 mg/L and 500 mg/L. The unit was operated without a recycle flow.

UA2 Results

The testing period for the UA2 is divided into four periods. Period 1, from May 24, 1994 through September 14, 1994, was when the UA 2's influent flow rate was between 0.1 and 0.12 gpm. Period 2, from September 15, 1994 through March 9, 1995, when the unit was shut down due to site flooding, was when the UA2's influent rate was targeted at 0.2 gpm. Period 3, from April 1, 1995 though October 31, 1995, was when the UA2 resumed operations after flooding at

an influent rate of 0.2 gpm. And lastly Period 4, from November 3, 1995 through November 16, 1995, was when the UA2 treated drainage water with a low concentration of selenium (total selenium concentration under 40 ug/L). Due to its short duration, Period 4 is not discussed and its operation and analyses data are absent from the figures. Period 4 data are included in the Appendixes Report. The Appendixes Report A through K contains operation and analytical results data for the project.

The overall results for selenium reduction are shown by Figures 77 and 78. Figure 77 shows the effluent concentration for total selenium, soluble selenium, and selenite, while Figure 78 shows the percentage of soluble selenium reduced and the dates for beginning of Periods 2 and 3. Influent selenium concentration data were previously presented in Figure 13. The best percentage Sse removal occurred in Period 1 and averaged 74%, while removal for Periods 2 and 3 averaged 24% and 57%, respectively.

The influent and effluent nitrate concentrations are shown on Figure 79. Nitrate reduction was best and most stable for Period 3. The effluent concentration averaged 5.6 mg/L as N, 11.3 mg/L as N, and 5.4 mg/L as N for Periods 1, 2, and 3, respectively, while the standard deviation for the three periods averaged 8.1 mg/L as N, 8.3 mg/L as N, and 5.4 mg/L as N.

Figure 80 shows the influent and effluent dissolved oxygen concentrations. The effluent DO concentration was consistently low for all three periods and averaged 0.6 mg/L, 0.7 mg/L, and 0.4 mg/L. Influent and effluent total organic carbon concentrations are shown by Figure 81. The influent TOC concentration was consistent through the entire testing period and averaged 13 mg/L. The effluent varied and averaged 27 mg/L, 65 mg/L, and 50 mg/L for the three periods. Figure 82 shows the influent total dissolved solids concentration was consistently greater than that of the effluent. The influent and effluent TDS concentrations averaged 8,239 mg/L and 7,924 mg/L, respectively, for the entire period.

Figure 83 shows influent and effluent alkalinity concentrations. The influent averaged 186 mg/L as CaCO_3 , while the effluent averaged 342 mg/L as CaCO_3 . The average difference, the influent value from the effluent value, was 152 mg/L as CaCO_3 .

The influent and effluent electrical conductivity values are shown by Figure 84. Except for a few instances, the influent was greater than the effluent value. The influent averaged 8,700 uS/cm for the entire period, while the effluent averaged 8,432 uS/cm.

Figure 77
UA2 - Effluent Total Selenium,
Soluble Selenium and Selenite

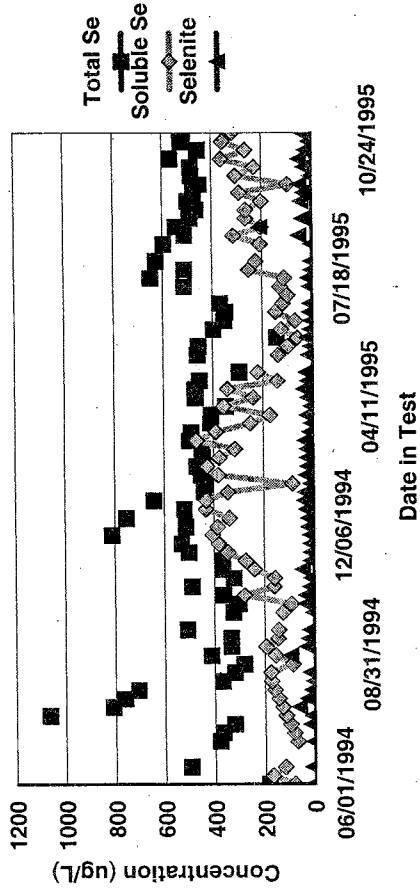


Figure 79
UA2 - Influent and Effluent
Nitrate

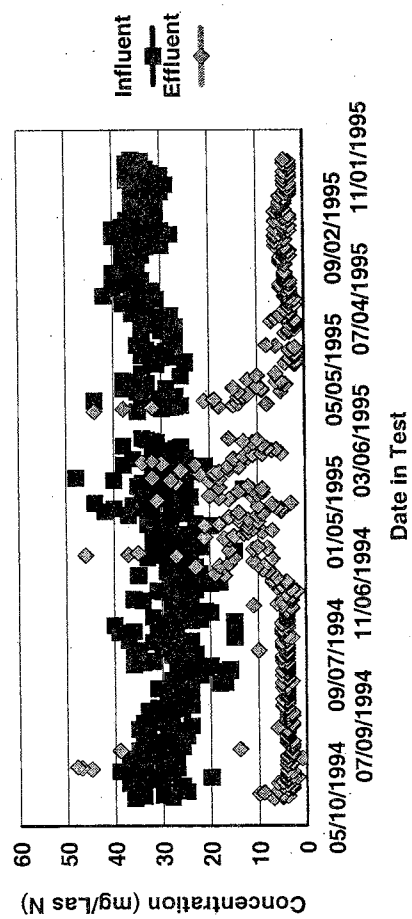


Figure 78
UA2 - Percentage of Soluble Selenium Reduced
and Dates for Influent Flow Change and Restart after Flooding

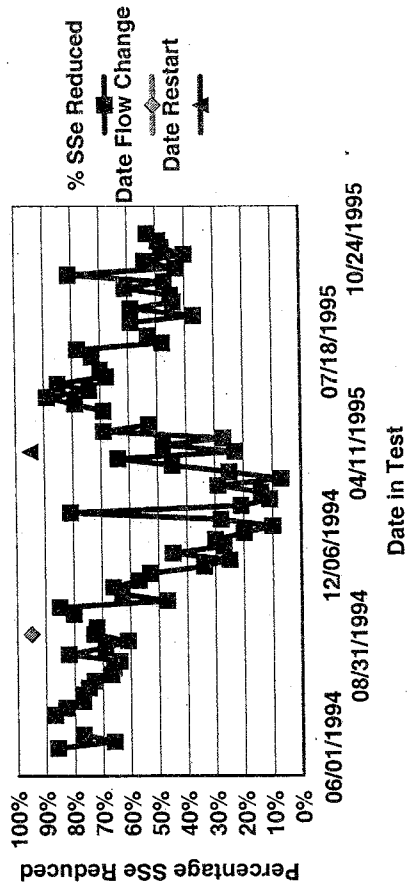


Figure 80
UA2 - Influent and Effluent
Dissolved Oxygen

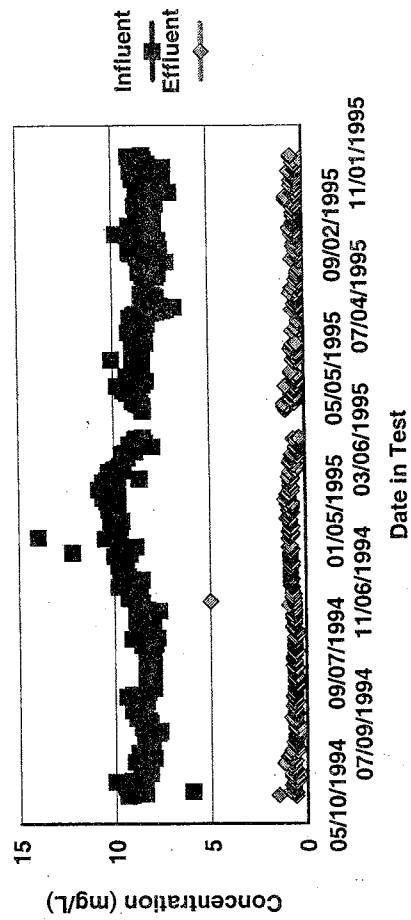


Figure 81
UA2 - Influent and Effluent
Total Organic Carbon

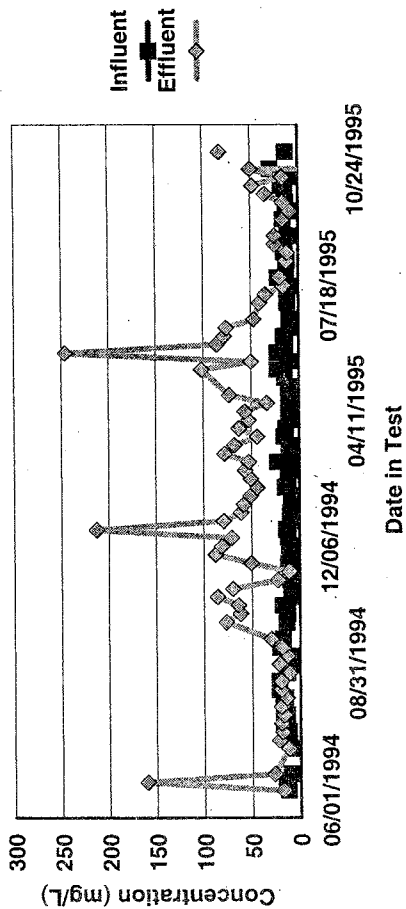


Figure 83
UA2 - Influent and Effluent Alkalinity

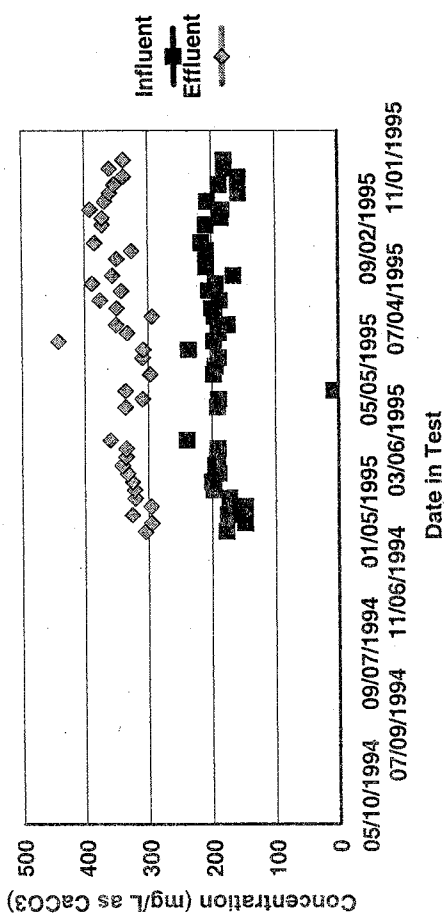


Figure 82
UA2 - Influent and Effluent
Total Dissolved Solids

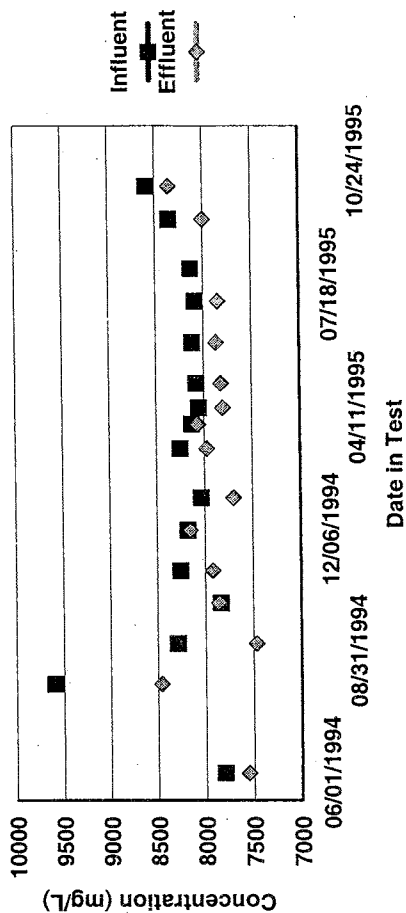


Figure 84
UA2 - Influent and Effluent
Electrical Conductivity

